Simulation of time-harmonic acoustic problems with a coupled isogeometric-meshless approach

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ABSTRACT

In the simulation of acoustic wave propagation, addressed by the Helmholtz equation, the Finite Element Method (FEM) is currently the most widely employed technique in commercial simulation tools. However, two main drawbacks are still present. First, the numerical results heavily depend on the regularity of the mesh used for the discretization, whose generation may take a significant part of the total analysis time, especially in three-dimensional applications. And second, the method suffers from dispersion errors in the higher frequency region, which requires very fine (and therefore computationally heavy) meshes for the simulation of short wave problems.

For this reasons in the last years literature focused also on alternative numerical techniques. Meshless methods are a possible solution for the first drawback. Concerning the second one, methods employing basis functions with higher order continuity are in general expected to perform better. In this framework isogeometric analysis [1] has been shown to significantly improve the accuracy with respect to FEM for Helmholtz problems [2]. Unfortunately this method does not possess the same flexibility as FEM in the volume discretization of complex shaped domains. While it is very easy to define a tensor product parameterization on a cube or on a sphere for instance, the problem becomes complicated when an arbitrary domain has to be represented. Even with the introduction of modified formulations such as T-splines, hierarchical B-splines and trimming techniques, this problem is still open in three dimensions.

In a recent work [4] a coupled isogeometric-meshless approach that elegantly solves this problem has been proposed. In particular the isogeometric parameterization is employed only on a thin region close to the boundary of the domain and then the isogeometric functions are blended with local maximum entropy (LME) mesh-free approximants [3] in the interior of the domain. This method appears particularly suitable for the simulation of the acoustic wave propagation problem since the LME basis functions are C^{∞}-continuous and therefore, like isogeometric methods, perform better than FEM in the higher frequency region. In addition, with the coupled approach, the correct geometric representation is preserved.

This study reviews the mathematical formulation of the method and considers some numerical applications, where the boundary of the domain is defined by a NURBS curve, including a two-dimensional car cavity geometry.

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